P.8

# INVESTIGATIONS INTO A POTENTIAL "LASER-NASP" TRANSPORT TECHNOLOGY

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# RENSSELAER POLYTECHNIC INSTITUTE

In this fourth year of the "Apollo Lightcraft Project" at RPI, the following question is asked of laser-boosted spacecraft technology: Can this technology also be used to repiace domestic and international jet flights? Clearly, if laser propulsion technology is less polluting than present jet transports, then it could become a major element in helping to reduce the problem of global warming. Also, if Lightcraft (or "laser-NASP") engines can be designed around solar satellite power sources and renewable propellants (e.g., air, LH<sub>2</sub>, LN<sub>2</sub>, H<sub>2</sub>O, etc.), then an enormous savings in hydrocarbon resources would be realizable.

This 1989-1990 annual report on RPI's design project begins with a first-order economic analysis of just such a beam-powered global transport system—based upon a fleet of 10,000 Lightcraft, designed to carry one, two, or five passengers in minimum volume capsules. A detailed conceptual design is presented for an on-place Mercury Lightcraft; other designs are briefly explored for larger, 15-place Executive Lightcraft, and 150- to 350-passenger Jumbo Lightcraft.

Various other teams in the class conducted experiments or performed theoretical analyses on various aspects of the Lightcraft propulsive engine and vehicle technology. One group machined an accurate, 6"-diameter model of the hypersonic air inlet (using a CNC lathe), instrumented it with PCB pressure transducers, and tested it from Mach 10 to 25 in RPI's hypersonic shock tunnel. Another group simulated the inlet aerodynamic performance with a computational fluid dynamic (CFD) code called PARC 2D. Analytically predicted shock positions and pressure distributions were then compared with Schlieren photographs and pressure data taken during the experiment.

One other group designed a laser propulsion experiment that will be carried out by the 1990-1991 design class. Another designed superconducting magnets for the laser-heated MHD-Fanjet engine, which accelerates a Lightcraft from Mach 10 to orbital velocity. Others built and tested a 1-1/4"-diameter Lightcraft inlet in RPI's Mach 3 wind tunnel, and analyzed the performance of the primary optics of a Mercury Lightcraft. Perhaps the most profound analytical achievement was the analysis of a laser-heated, rocket-driven MHD generator using 20,000° K hydrogen as the working fluid; the method employed a combined simultaneous solution of a quasi-1D MHD code with a 3D radiation code.

In summary, the class design team made exceptional progress in continuing to climb the steep learning curve on laser-propelled flight/transport technology.

# INTRODUCTION

Technological innovation has repeatedly caused drastic revolutions in world travel patterns. The schooner, steamship, dirigible, and airplane all had their profound effects. Here we present an economic analysis of yet another new transport mode that will make the advances of these former modes seem like microscopic progress. We are talking about the Apollo Lightcraft, a technology that will allow people to travel half-way around the world, essentially door-to-door in 45 minutes. It will make trips possible that simply cannot be made today except by astronauts. And our economic analysis tends to show that the operating and capital costs of this system can be recovered once the Lightcraft technology is mature.

### BACKGROUND

It is well recognized that mankind's quest for increased speed has not yet abated, not even with the introduction of the supersonic Concorde. In fact, the Concorde has merely whetted our appetite for faster, futuristic flight. People want to reach their destination as quickly as possible. Two recent proposals have heightened our interest in travel time savings: the High Speed Civil Transport (HSCT) and the Hypersonic Aircraft (HA)<sup>(1)</sup>. The HSCT is the next step in the development

of supersonic transports and the Hypersonic Aircraft is a jump beyond the HSCT. The HSCT is much closer to today's technology, and advanced studies have been conducted on the marketability of this technology in the growing international transportation market<sup>(2,3,4,5,6,7,8)</sup>.

But these advances in high speed transport technology have generated an interesting dilemma—namely, while the systems must be cost effective to be saleable, increasing speed also increases costs. This "Catch-22" is readily apparent when considering the HSCT. While it has been proposed that the HSCT needs a range of at least 7500 n.m. to be profitable (the range of current 747-400 technology), at this range and at Mach 2.5, it requires twice the fuel of the 747 to carry the same number of passengers, and at Mach 3.5 it needs nearly four times the fuel. It seems that as range increases, fuel requirements grow at an exponential rate (see Fig. 1)<sup>(9)</sup>.

Clearly the success of the HSCT and other super- or hypersonic transports is dependent on an ability to produce these travel-time savings. Fuel consumption is a major problem, but the real trouble is that the time savings can only be pushed to a certain limit, beyond which access and egress times (i.e., the times spent going to and from the airports) become the real liability. Also, since supersonic speeds are possible only

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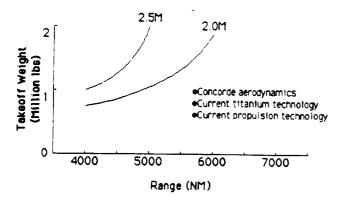


Fig. 1. HSCT Fuel Consumption (Weight) vs. Range<sup>(9)</sup>

over water, only certain city pairs can benefit from the time savings that can be achieved. The inability to fly supersonic over land also has serious impacts on flight paths. A flight from Paris to Tokyo, for example, requires either a subsonic track over land, or an extended diversion to fly completely over water. Moreover, travel becomes complicated as more changeovers at intermediate airports become necessary.

For these reasons, while the HSCT may increase flight speed over water by a factor of three, it may reduce overall travel time by only 50% or less. Note that the over-water flight time is not total travel time, but merely over-water air time; overland air time and access and egress times are additional. This becomes quite important when one considers how many airports will be capable of supporting an HSCT system. If an HSCT network is only partially implemented, access and egress times to HSCT port cities could be quite long. This inability to effect major travel time savings will clearly limit the marketability of the HSCT and other such super- or hypersonic transport.

HSCT proponents hope to capture the top 25% of the international travel market in spite of these limitations. And they think they can do this in spite of what they expect to be a 30% differential in fares. Helping the HSCT is an assumption that the reduced travel times will stimulate demand. Historically, reduced travel times have stimulated travel by a factor of 1.25 to 1.5<sup>(5)</sup>.

# APOLLO LIGHTCRAFT TECHNOLOGY

The real question is not whether the HSCT (or some other high speed transport) can be developed in the near term, but how much longer we will or should continue to base future air transport schemes on large aircraft and fossil fuels. This is where the Apollo Lightcraft technology fits in<sup>(10,11,12)</sup>. The Lightcraft (see Fig. 2) is not an extension of current aircraft into the next century, but a categorically different technology because of many unique features. First, and most obviously, a Lightcraft has a propulsion system that is not powered by fossilfuels. It uses laser beams transmitted from satellite solar power stations (SPS)<sup>(13,14)</sup>, for the propulsive energy source (see Fig. 3). Size is another difference. A Lightcraft is designed to carry

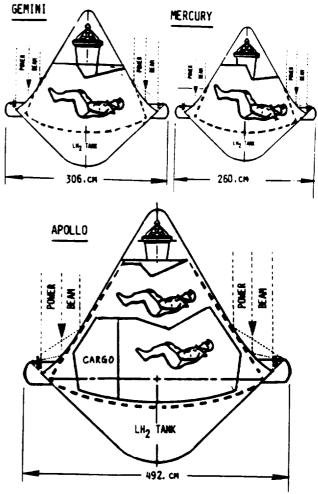


Fig. 2. Family of Laser Boosted Lightcraft(11)

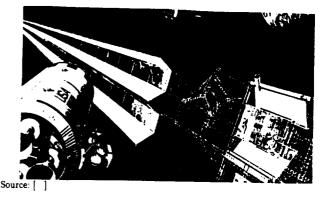


Fig. 3. 7 GW<sub>e</sub> Satellite Solar Power Station

only one to five persons. Second, it is designed to take off and land from any airport equipped with a Lightcraft landing pad (see Fig. 4). Third, its range is unlimited. In fact, it becomes more cost effective the further it travels. Unlike the HSCT and hypersonic aircraft, it does not carry its own energy source,

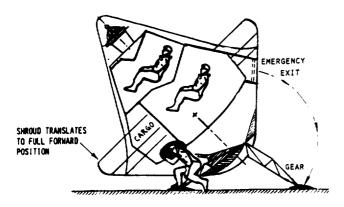


Fig. 4. Passenger Entrance and Egress (Gear Permits Pointing to Laser Power Satellite)

and does not need exponential fuel increases to increase range. Most of its flight is exoatmospheric, and its reentry is performed much like the shuttle (see Fig. 5). Fourth, a Lightcraft not only minimizes inflight travel time, but also access and egress times. The result is that total travel time is dramatically reduced, so much so for long trips that no data presently exist to suggest how profound the effect will be. Fifth, a Lightcraft is not dependent on fossil fuels. Its electricity needs can be provided by large solar power stations (SPS) positioned in geostationary orbit.

# PROJECTION OF FUTURE DEMAND

The projectons of Lightcraft demand presented here assume that the technology will compete with the HSCT and, over time, successfully capture a certain percentage of that marketplace. They also assume that Lightcraft system fares will be competitive with the HSCT and that network travel times will be at least as short if not shorter.

We expect the rate of penetration will be slow at first (see Fig. 6) then grow more rapidly as the technology becomes accepted, and finally stabilize at 25% of the marketplace. We assume 20 years will be required to accomplish this, both because the Lightcraft is an entirely new technology that will

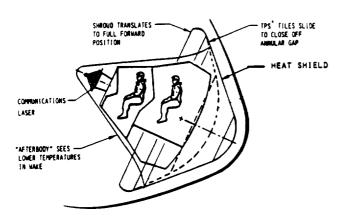


Fig. 5. Re-Entry Configuration

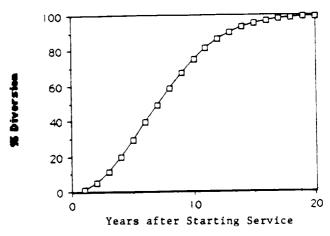


Fig. 6. Growth in the percent of HSCT riders using Lightcraft during the first 20 years

require an extended public acceptance time and because the support infrastructure for the Lightcraft system will take time to complete.

Given this market penetration curve (i.e., Fig. 6) and projections of HSCT demand, ridership for the Lightcraft system can be estimated (see Table 1). We have considered two scenarios. In scenario A, it is assumed that the Lightcraft system will capture 25% of the HSCT ridership projected by Wasiuta<sup>(7)</sup>. (This HSCT ridership projection calls for a compounded 4%/year growth in long-distance air travel until 2015. To be conservative we have assumed no growth thereafter.) In scenario B, an additional stimulation factor of 2.5 has been applied (to the total long-distance ridership estimate) based on the time savings the Lightcraft system will produce.

To ensure that the scenario B estimate is not unrealistic, a cross-check has been made, based on a top-down analysis starting from world population figures. Details on this scenario C are given in Table 2. The analysis year is 2015 (Year 0 for the market penetration curve) when the world population will be approximately seven billion. Table 2 first shows that about 1.56 trips over 4000 miles will be generated by a typical 4

Table 1. Lightcraft Revenue Estimates (1989 dollars)

	Plea	ısure	Business	
	Long	Short		
Trips/year/household	3	10	30	
Person/trip/household	4	2	1	
Person-trips/yr/hh.	12	20	30	
% over 4000 miles	<b>3</b> %	3%	2%	
Person trip> 4000 mi/hh	0.36	0.6	0.6	
Total person trips over				
4000 miles per household		$= 1.56  \mathrm{pa}$	ss./family	
World population		=7,000	,000,000	
No. of households		1,750	000,000,	
%-hh involved			2%	
Person-trip/yr over 4000 mi		54	,600,000	
Person-trip/day over 4000 mi			149,600	
Implied trip expansion factor			2.5	

Table 2. Calculations for Scenario C

Year	Dvrsn (%)	Revenue A	PV of A	Revenue B	PV of B
1	1.38	\$217	\$20	\$543	\$50
2	5.39	<b>\$85</b> 0	\$71	\$2,126	\$178
3	11.73	\$1,849	\$141	\$4,623	\$353
4	19.89	\$3,136	\$217	\$7,8 <del>4</del> 0	\$544
5	29.18	\$4,618	\$291	\$11,544	\$728
6	39.28	\$6,19 <del>4</del>	\$355	\$15,486	<b>\$887</b>
7	49.29	\$7,773	\$405	\$19,432	\$1,012
8	58.81	\$9,274	\$439	\$23,184	\$1,098
9	67.46	\$10,637	\$458	\$26,592	\$1,145
10	74.99	\$11,825	<b>\$463</b>	\$29,562	\$1,157
11	81.31	\$12,821	<b>\$456</b>	\$32,052	\$1,141
12	86.41	\$13,625	<b>\$441</b>	\$34,063	\$1,102
13	90.39	\$14,253	\$419	\$35,632	\$1,048
14	93.39	\$14,726	\$394	\$36,814	\$984
15	95.58	\$15,071	<b>\$366</b>	\$37,677	\$916
16	97.12	\$15,314	<b>\$338</b>	\$38,286	<b>\$84</b> 6
17	98.18	\$15,481	\$311	\$38,702	\$777
18	98.88	\$15,591	\$285	\$38,978	\$712
19	99.33	\$15,662	\$260	\$39,155	\$650
20	100.00	\$15,768	\$238	\$39,420	\$595
Total		\$204,684	\$6369	\$511,709	\$15,923

person household. With world population at 7 billion (implying 1.75 billion such households), and with 2% of these households making such trips, the number of person-trips per year over 4000 miles is estimated to be 54.6 million. On a daily basis, this is 149,600 trips. Compared with the total long-distance air travel projections presented<sup>(7)</sup>, this implies a trip expansion factor of 2.5. While these estimates are crude, they do show that scenario B is not impossible, and, if the jumps in ridership seen in the past repeat themselves, a growth factor of 2.5 may occur, given the time savings that the Lightcraft system will produce.

To estimate annual revenues, we have taken the ridership estimates presented in Table 1 and multiplied by \$0.12 per passenger mile, a revenue estimate that has been used in the HSCT analyses<sup>(7)</sup>. We have also assumed an average trip length of 5000 miles.

To estimate the net present value of these revenues, for either scenario A or B, a discount rate of 210% has been used, as is typical for somewhat risky investment opportunities and/or programs involving the use of governmental funds. Under scenario A, the net present value of the revenues is thus \$204 billion in 1989 dollars; for scenario B, it is \$511 billion.

# STRUCTURE OF THE LIGHTCRAFT INDUSTRY

We foresee a commercialization of the Lightcraft network similar to that of the present automobile rental industry for the following reasons. First, Lightcraft will tend to be used like rental cars. Small groups of people will use them on an occasional basis to make very long distance trips. Table 2 suggests that for scenario C (described earlier) only 1.566 passenger trips per year will be generated on average by the typical four-member Lightcraft-user household. At this rate, only a few households will use them enough to justify owning them privately.

Second, Lightcraft will be very different from existing wide body aircraft, more closely resembling the family car; thus airlines are not likely to be interested in them. Economies of scale due to vehicle size, to which the airlines have become accustomed, simply will not exist. In fact, since Lightcraft will be able to take off and land at virtually any airport, (i.e., any one equipped with a proper vertipad) the Lightcraft network will effectively become a long-distance, high-speed extension of the present private (auto) transportation system. Third, the capital cost of a Lightcraft will be high. Relative to the cost of a present-day commercial airplane, Lightcraft will be inexpensive, having a cost per pound about on par with corporate business jets (see discussion below), mainly due to the fact that a Lightcraft will not have to carry its own propulsion plant. (It will usually be a capsule moved by efficient beamed-energy engines around the planet and/or into space.) But, nonetheless, corporate, rather than private, individual financing will probably be required to purchase them, and rental companies will be well poised to arrange for such financing.

#### SUPPLY ANALYSIS

In the supply analysis, we have attempted to determine the net present value of the costs of creating and operating the Lightcraft system over a 20-year time horizon (2015 to 2035). This is the timeframe over which implementation of the system is expected.

We have assumed that remote energy sources (i.e., SPSs) will be available to power the Lightcraft system, that 500 will eventually be required, and that the vehicle technology will already be mature.

The cost analysis was accomplished by estimating capital expenditures and then analyzing operating costs. The operating cost of a Lightcraft depends basically on the beamed energy requirement plus a small quantity of liquid hydrogen needed for energy conversion during laser boost. It should be noted that very little hydrogen is needed on short endoatmospheric flights where the Lightcraft does not reach hypersonic velocities. In addition to the energy requirements, maintenance expenditures will be required, but this is covered in the capital costs. In theory, the Lightcraft should have a low maintenance cost because of its combined-cycle engine, which has no moving parts. One sensitive area is the large receptive laser mirror, which may require maintenance of its adaptive surface actuators, or repair of minor scratches or marring of the surface.

For purposes of this analysis, the assumed cost for the liquid hydrogen is \$975 for a five-person Lightcraft traveling half-way around the globe. This number is based on 1987 dollar values for liquid hydrogen. It has been suggested that liquid hydrogen prices will decrease with increased demand (especially if the "hydrogen economy" materializes). This is one of the founding philosophies behind the push for hypersonic transport, where it has been assumed that fuel prices will be cut in half. The present study assumes that liquid hydrogen prices will remain at their 1987 levels. The price used for electricity is \$.017/kWh, from estimates for the SPS electric power sources

mentioned previously. It includes price surcharges that would be added to the base kWh charge to account for fluctuations in demand.

Table 3 shows a chart of the energy and hydrogen costs for various trip lengths in the three different Lightcraft sizes. Obviously, these data are an estimation of costs at the prices mentioned above. The costs incorporate predicted losses in the conversion of electricity into laser light at the power source. Also, they represent a linear extrapolation of cost for a trip to the farthest point on Earth in the five-person Apollo Lightcraft. The linear reduction in cost with decreasing trip length is a conservative projection because the costs for the 12,000-mile trip are actually those required for the Apollo Lightcraft to achieve orbit; thus any of the shorter missions will not need more hydrogen, and will require considerably less electricity than a linear extrapolation. As far as the vehicle sizes are concerned, the two-person "Gemini" vehicle (see Fig. 2) is estimated to need 1/2 the energy of the five-person vehicle (as opposed to 2/5 based on the number of passengers). Similarly, the single-passenger Mercury unit is assumed to require 1/3, instead of 1/5. Obviously, these assumptions are based on the increased efficiency of carrying more passengers in a single vehicle, since the payload is only 9% of the takeoff weight for the largest Lightcraft. It should be noted, however, that this logic cannot be extended indefinitely. In fact, calculations have shown that a five-person Apollo vehicle is close to being the largest feasible craft due to the 2.5-GW propulsive laser beam needed from a 7-GW SPS with a 40% efficient laser and 90% beam transmission efficiency. Additionally, these direct operating costs include a \$100 landing fee per flight.

Table 3. Energy Costs for Various Trip Lengths

Trip Length (mi)	Lighto	raft Capacity (pas	sengers)
	5	2	1
12,000	<b>\$</b> 3530	\$1815	\$1243
10,000	\$2958	\$1529	\$1052
8,000	\$2387	\$1244	\$862
6,000	\$1815	<b>\$</b> 958	\$671
4,000	\$1243	\$672	\$480

Figure 7 shows estimated group sizes for Lightcraft flights. These are used to calculate the number of vehicles required for each vehicle size. Distribution among the various craft sizes is based upon the above estimates plus additional conditions that 10% of the single passengers will team up to form doubles and that 5% of the doubles will group to form four- (or five-) member flights. Table 4 shows the number of daily revenue flights necessary to service the passenger groups shown above. These figures are based on 150,000 passengers per day, the number corresponding to scenario B, and must be upwardly adjusted to compensate for repositioning, spares, and peak demand. Then, the fleet size can be calculated. Finally, capital expenditures can be estimated to show investment in fleet according to traffic diversion, so that capital costs can be estimated on a per flight basis.

The first adjustment that must be applied is for repositioning. In our analysis, we have assumed that 50% of all flights must be repositioned. This is conservative in light of most

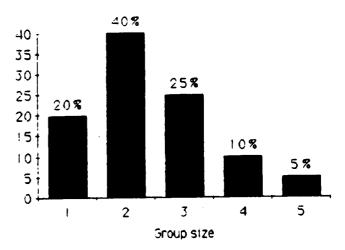


Fig. 7. Assumed Passenger Grouping

automobile rental company experience, but provides a reasonable worst-case scenario for estimating cost. As traffic increases, the repositioning factor will eventually diminish to a much smaller value (e.g., 5-10%), thus reducing costs with a greater number of flights (this has not been taken into account here). It is assumed that the energy costs for repositioning would be charged to the users. This will tend to encourage passengers to fly to well-traveled areas, while retaining the ability to fly nearly everywhere. The resulting flights are as follows: 40,500 singles, 47,250 doubles, and 29,500 quintuples.

After adjusting the number of flights for repositioning, a first estimate of the fleet size can be prepared, ignoring peaking in demand and spares. Since the longest flight will take approximately 45 minutes, Lightcraft should be able to fly every 2 hours, leaving the remaining time for loading, unloading, and any routine inspections or maintenance that must be done. This results in 12 flights per day per Lightcraft. The fleet size at this stage would be 3375 singles, 3938 doubles, and 2438 quintuples.

From this fleet size, the number of vehicles must be adjusted upward to account for peaking in demand. The first reason for doing so is that demand will be higher on some days than others. Day of the week and month of the year will both have an effect, let alone variations from year to year for a given day. Peaking due to religious and national holidays can be ignored

Table 4. Daily Flights by Lightcraft Size in Year 20°

Group size	No. of passengers	1 person craft	2 person craft	5 person craft
1	30,000	27,000	3,000	
2	60,000	28,500	1,500	
3	37,500			12,750
4	15,000			3,750
5	7.500			1,500
Revenue	. ,-	27,000	31,500	19,500

<sup>\*</sup>These 78,000 flights per day represent 150,000 flights per year and 15,000 payload tons lifted into space each day.

because we are dealing with the entire world population. Peakings in such demand will tend to offset one another. Non-Christians, for example, will still be willing to travel on Christmas, while non-Americans will want to travel on Thanksgiving. The result will be that national religious holidays will not have a significant effect on Lightcraft travel. Rather than deal with these phenomena at a detailed level, a 300-day year has been assumed. This means adjusting the fleet size upward by a factor of 365/300, resulting in an approximate 20% increase. Once this number has been calculated, an adjustment must also be made for spares. A 10% spare ratio has been assumed. This means 10% of the fleet will be out of service for repair, implying the fleet size must be increased by another 9%.

Finally, estimates must be made for the cost of the Lightcraft vehicles. This is perhaps the most difficult task. In the long run, with mass production, Lightcraft might become quite inexpensive. For the time being, however, we have assumed that today's typical business jet and propjet prices will pertain (i.e., \$250/lb). At \$250/lb, the one-passenger Mercury Lightcraft would cost \$0.717 million, the two passenger Gemini, \$1.43 million, and the Apollo vehicle, \$3.06 million.

Given these assumptions and calculations, Table 5 shows that the five-person unit could actually become the cheapest means of transportation in the long-distance travel market. Even the single-capacity Mercury will be competitive with the HSCT. If so, the implications are tremendous. The Lightcraft network might be capable of capturing the entire long-distance international market, rather than just the 25% of the HSCT market as we assumed. This would considerably change the results presented here.

The final information presented in Tables 6 and 7 pertains to the total costs involved. This is useful not only for showing the capital expenditures required throughout the implementation of the Lightcraft network, but also for comparison to the revenue estimates made previously. Using the same discount rate of 10%, the values obtained from this table should hold the same present value as those derived from

revenue estimates. The present values are important because expenditures will precede revenues. Table 6 shows that capital costs will occur over a period of 16 years, 4 years less than the 20 years analyzed in the revenue estimates. The maintenance and operating cost expenditures given in Table 7, however, will logically coincide with revenue.

The total present value of costs for the Lightcraft system is \$12,982 million. This can be compared with net present value of \$15,923 million for the revenue estimate.

### CONCLUSION

This paper has examined the economic prospects for a revolutionary new aerospace transport system based upon the Lightcraft technology, which, when operational, will enable people to fly half-way around the world in 45 minutes. Based on what we know to date, it appears the new technology will be able to cover both its operating and capital costs, with at least an 18% margin to spare, allowing ticket prices below any other Mach 1 or higher transport options. Developers should be encouraged to push Lightcraft prototype work through to completion in the next half decade, because it is simply a matter of time before this mode becomes the principal means for long-distance international travel.

### POSTSCRIPT

Figure 8 shows the number of satellite solar power stations (SPSs) and launches per day needed to satisfy projected demands for the Lightcraft network. The calculations assume 50% repositioning and a five-minute boost duration, 7GW<sub>e</sub> SPS capacity with 40% laser-to-electric power conversion efficiency, and 90% beam transmission efficiency for continuous global service. Note that in Year 20, 509 SPSs are required to provide this service, which represents 25% of the total world market. If the Lightcraft network captures the complete world market, roughly 2000 SPSs will be required by Year 20.

It is interesting to compare this result with current 1989 U.S. and world energy consumption. The present U.S. ground

Table 5. Development of	Costs per Passenger	r per Flight, by Lighto	raft Size (1989 dollars)

Trip Len	Veh. Cost	10%	Maint	Rev Fl/yr	Cap Cost Fl	Oper. Cost	Total/pax
		(a	) Single pass	enger lightc	raft		
12,000	\$715,000	\$71,500	\$14,300	2,190	<b>\$3</b> 9	\$1, 243	\$1,282
10,000	\$715,000	\$71,500	\$14,300	2,190	\$39	\$1,052	\$1,091
8,000	\$715,000	\$71,500	\$14,300	\$2,190	\$39	<b>\$86</b> 2	<b>\$</b> 901
6,000	\$715,000	\$71,500	\$14,300	2,190	\$39	<b>\$</b> 671	\$710
4,000	\$715,000	\$71,500	\$14,300	2,190	\$39	\$480	\$520
		a	) Two passe	nger lighten			.,_,
12,000	\$1,430,000	\$143,000 `	\$28,600	2,190	\$78	\$1,815	\$947
10,000	\$1,430,000	\$143,000	\$28,600	2.190	\$78	\$1,529	\$804
8,000	\$1,430,000	\$143,000	\$28,600	2,190	\$78	\$ 1,244	<b>\$</b> 661
6,000	\$1,430,000	\$143,000	\$28,600	2,190	\$78	<b>\$</b> 958	\$518
4,000	\$1,430,000	\$143,000	\$28,600	2,190	\$78	\$ 672	\$375
		(	c) Five passe	nger lightere			-312
12,000	\$3,052,500	\$305,250 `	\$61,050	2,190	<b>\$</b> 167	\$3,530	\$739
10,000	\$3,052,500	\$305,350	\$61,050	2,190	\$167	\$2,958	\$625
8,000	\$3,052,500	\$305,250	\$61,050	2,190	\$167	\$2,387	\$511
6,000	\$3,052,500	\$305,250	\$61,050	2,190	\$167	\$1,815	\$396
4,000	\$3,052,500	\$305,250	\$61,050	2,190	\$167	\$1,243	\$282

Table 6. Lightcraft Capital Costs

 Year	Dvrsn (%)	Year (%)	Singles	Doubles	Five-man	Capital(\$Mil)	PV(\$Mil)
		11.73	522	610	377	2,397	221
1	11.73	8.16	364	424	263	1,668	140
2	19.89		419	488	302	1,920	146
3	29.28	9.39	-	520	322	2,044	142
4	39.28	10.00	445		322	2,046	129
5	49.29	10.01	446	520	306	1,946	112
6	58.81	9.52	424	495	-	1,767	92
7	67.46	8.65	385	449	278	1,540	73
8	74.99	7.53	336	392	242		56
9	81.31	6.32	281	328	203	1,291	
10	86.41	5.10	227	265	164	1,043	41
11	90.39	3.98	177	207	128	814	29
12	93.39	3.00	134	156	97	613	20
		2.19	97	114	70	447	13
13	95.58	1.54	69	80	50	316	8
14	97.12		47	55	34	216	5
15	98.18	1.06		95	59	372	8
16	100.00	1.82	81		3218	20,441	1235
Total			4455	5198	3216	20,111	

Table 7. Lightcraft Maintenance and Operating Costs

Year	Dvrsn (%)	Maint(\$Mil)	PV(\$Mil)	Oper (\$Mil)	PV (\$Mil)
		48	4	423	39
1	1.38	81	7	1,657	139
2	5.39		ý 9	3,603	275
3	1.173	120	ıí	6,110	424
4 5	19.89	161	13	8,996	567
5	29.28	202		12,068	692
6	39.28	240	14		789
7	49.29	276	14	15,143	856
8	58.81	<b>307</b>	15	18,067	
9	67.46	332	14	20,723	892
10	74.99	353	14	23,037	902
11	81.31	370	13	24,977	889
12	86.41	382	12	26,544	859
	90.39	391	11	27,767	817
13	93.39	397	11	28,689	767
14		401	10	29,361	714
15	95.58	409	9	29,835	659
16	97.12	162	3	30,160	659
17	98.18		3	30,375	555
18	98.88	162	3	30,513	507
19	99.33	162	2	30,719	464
20	100.00	162	_	398,763	12,408
[otal		5117	193	390,703	

electric power grid supplies roughly 80 quadrillion Btu (i.e., QUADS), of which 85-90% comes from fossil fuel plants. This power could be provided by 150 SPSs (e.g., 7 GW<sub>e</sub> each, at the SPS; 65% transmission efficiency to groundbased receiving antennae; 5 GW<sub>e</sub> into each of the grids)<sup>(13)</sup>.

All U.S. energy needs (i.e., transportation, industrial, domestic, etc.) could be covered by 500 SPSs. Since world consumption is 4 times that of the U.S., 2000 SPSs, spaced 40 to 50 miles apart in geostationary orbit would be needed for the whole planet.

It is also useful to compare the total payload moved per day on the Lightcraft network, with that of the space shuttle orbiter (65,000 lb or roughly 30 tons maximum). Figure 8 shows that in Year 20, 15,000 tons of paying passengers and baggage will be moved daily on the Lightcraft network. This will be equivalent to 500 shuttle launches each day.

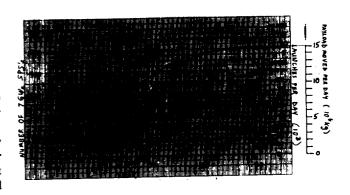


Fig. 8. Number of SPSs and launches per day vs. year

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